

Exercise walk-through

4.4

Elastic and Inelastic Collisions

AP Physics 1

Elastic and inelastic collisions

Momentum is conserved in **every** collision; kinetic energy is not.

- **elastic** – KE conserved
- **inelastic** – some $KE \rightarrow$
heat, sound
- **perfectly inelastic** –
they stick

Worked example (stick together)

2 kg at 3 m/s hits a 4 kg at rest:

$$2(3) = (2+4)v_f \Rightarrow v_f = 1 \text{ m/s}$$

KE : 9 J $\rightarrow$ 3 J; the missing 6 J became heat.

Which conservation law to write, and when

always

write **momentum conservation** – it holds in every collision

only if stated elastic

add **kinetic energy conservation** as a second equation

perfectly inelastic

the bodies stick together, so they share one final velocity – one unknown instead of two

the elastic fact worth remembering

for a head-on **elastic** collision, the **relative velocity of approach equals the relative velocity of separation**

centre-of-mass velocity

$\vec{v}_{\text{cm}} = \frac{\sum m_i \vec{v}_i}{\sum m_i}$ – unchanged by any internal collision

why that helps

the centre of mass moves at constant velocity throughout, whatever the bodies do to each other

Assuming kinetic energy is conserved when the question has not said “elastic” is the standard error. Momentum first, energy only on invitation.

The centre-of-mass velocity

the definition

$$\vec{v}_{\text{cm}} = \frac{\sum m_i \vec{v}_i}{\sum m_i} - \text{the mass-weighted average velocity}$$

what it does

a whole collection of objects can be described by this **single** velocity

the key property

internal forces cannot change it, so it is **unchanged by any collision or explosion**

the consequence

in a collision with no external force, the centre of mass keeps moving at constant velocity throughout

the shortcut

in the centre-of-mass frame the total momentum is **zero**, which makes many collisions symmetric

an explosion

fragments fly apart, and their centre of mass carries on along the original path

Conservation of momentum and constant $\vec{v}_{\text{cm}}$ are the same statement. Using the second is often the faster route through a two-body problem.

The centre of mass keeps moving

Center-of-mass velocity

The **center-of-mass velocity** is $\vec{v}_{cm} = \frac{\sum m_i \vec{v}_i}{\sum m_i}$ – the total momentum divided by the total mass.

Why it matters

With no external force it does not change, whatever the parts do to each other in a collision or an explosion.

Using it

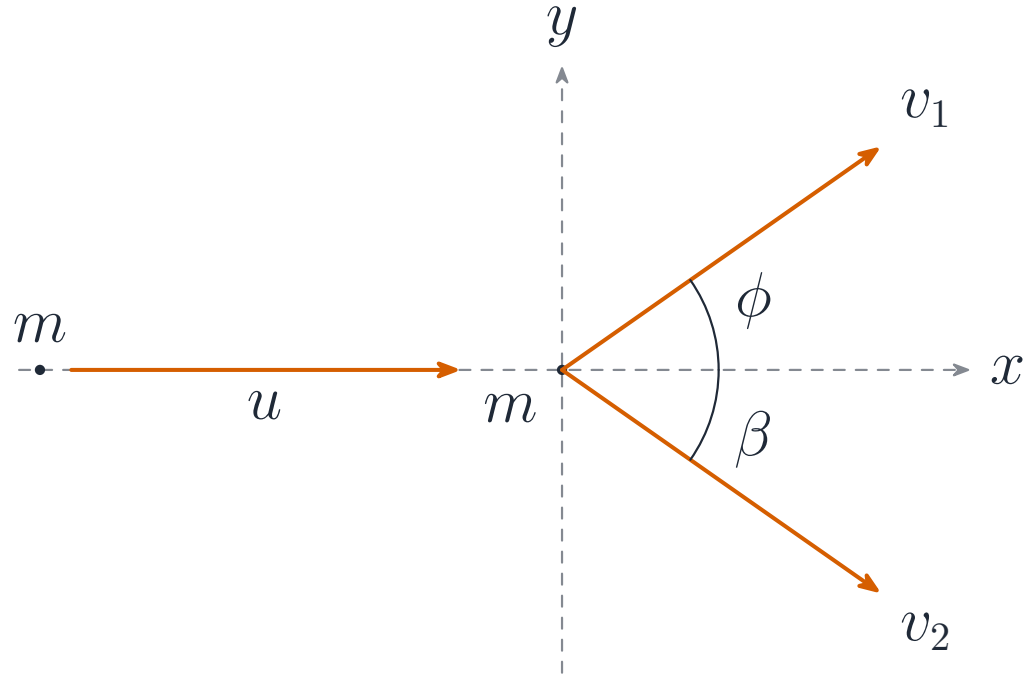
In a perfectly inelastic collision the objects end up moving at $\vec{v}_{cm}$ – which gives the final velocity with no algebra.

A check

Work in the centre-of-mass frame and the total momentum is zero, before and after.

“Momentum is conserved” and “the centre of mass keeps its velocity” are the same statement.

A glancing collision



A glancing collision, resolved along two perpendicular axes

Exercises 2.1·2.2

2.1 State what is conserved in (a) an elastic collision and (b) an inelastic collision. [2]

2.2 A 1.0 kg ball at 6.0 m s^{-1} strikes a stationary 2.0 kg ball and they stick together. Find their common speed. [2]

Exercises 2.1-2.2

2.1 State what is conserved in (a) an elastic collision and (b) an inelastic collision. [2]

2.1

(a)

- both momentum and kinetic energy

(b)

- momentum only

2.2 A 1.0 kg ball at 6.0 m s^{-1} strikes a stationary 2.0 kg ball and they stick together. Find their common speed. [2]

2.2

- $1.0(6.0) = (1.0 + 2.0)v \Rightarrow v = 2.0 \text{ m s}^{-1}$

Exercises 2.3-3.1

2.3 For the collision in 2.2, find the kinetic energy lost.

[2]

3.1 In a perfectly inelastic collision, the objects

[1]

☐

A bounce apart

B stick together

C conserve kinetic energy

D reverse direction

Exercises 2.3-3.1

2.3 For the collision in 2.2, find the kinetic energy lost. [2]

2.3

- KE before = $\frac{1}{2}(1.0)(6.0)^2 = 18 \text{ J}$; after = $\frac{1}{2}(3.0)(2.0)^2 = 6.0 \text{ J}$; lost = 12 J

3.1 In a perfectly inelastic collision, the objects [1]

☐

A bounce apart

B stick together

C conserve kinetic energy

D reverse direction

3.1 B

- stick together.

Exercise 3.2

3.2 Kinetic energy is conserved in

[1]

☐

A all collisions

B elastic collisions only

C inelastic collisions only

D explosions only

Exercise 3.2

3.2 Kinetic energy is conserved in

[1]

☐

A all collisions

B elastic collisions only

C inelastic collisions only

D explosions only

3.2 B

- elastic collisions only.

Exercise 3.3 (a)

3.3 A 0.50 kg cart at 4.0 m s^{-1} hits a stationary 0.50 kg cart, and they move off together.

(a) Find their common velocity.

[2]

Exercise 3.3 (a)

3.3 A 0.50 kg cart at 4.0 m s^{-1} hits a stationary 0.50 kg cart, and they move off together.

(a) Find their common velocity. [2]

(a)

- $0.50(4.0) = (1.0)v \Rightarrow v = 2.0 \text{ m s}^{-1}$

Exercise 3.3 (b)

3.3 A 0.50 kg cart at 4.0 m s^{-1} hits a stationary 0.50 kg cart, and they move off together.

(b) By calculating the kinetic energy before and after, state whether the collision is elastic. [2]

Exercise 3.3 (b)

3.3 A 0.50 kg cart at 4.0 m s^{-1} hits a stationary 0.50 kg cart, and they move off together.

(b) By calculating the kinetic energy before and after, state whether the collision is elastic. [2]

(b)

- KE before = $\frac{1}{2}(0.50)(4.0)^2 = 4.0 \text{ J}$; after = $\frac{1}{2}(1.0)(2.0)^2 = 2.0 \text{ J}$; not conserved, so it is **inelastic**